Supply and Services Canada

Study Report

Pilot Application of Expert System Technology to Process Control

March 88

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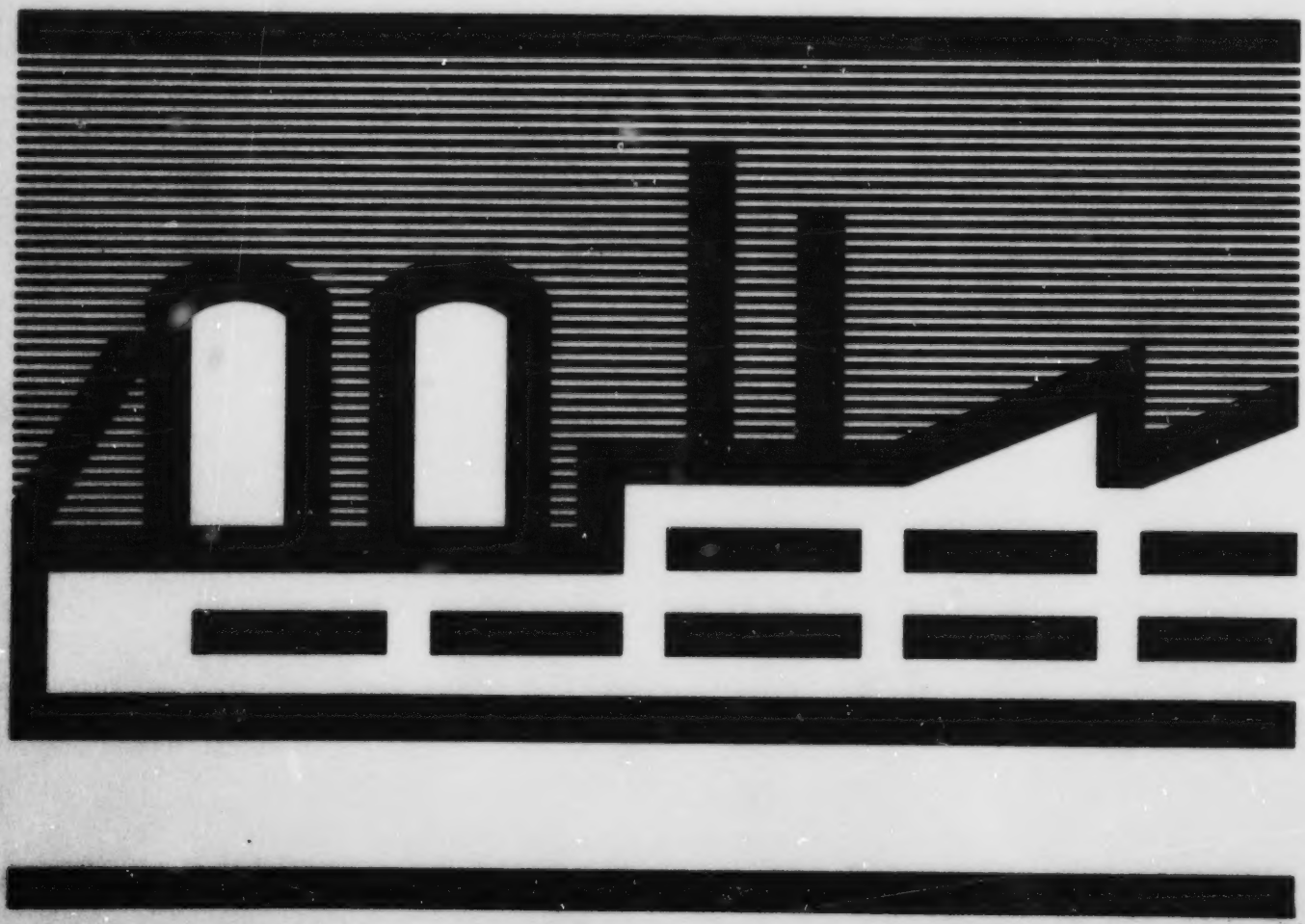

Lavalin

6-9137

STUDY REPORT

By Ivan Farner and Louis Lapointe, M. eng.,
under the scientific authority of Daniel Laguitton (D.Sc)
of the Canada Centre for Mineral and Energy Technology (CANMET)

PILOT APPLICATION OF EXPERT SYSTEM TECHNOLOGY FOR PROCESS CONTROL

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MICROMEDIA

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1) PROJECT SCHEDULE

November 7, 1986	Start of project meeting and creation of work committees (obtaining the knowledge, information systems, etc.) at Lavalin's Montreal offices.
November 13, 1986	Knowledge engineering meeting at the CEZ plant in Valleyfield.
December 22, 1986	Presentation by CEZ, tour of the Hydrometallurgy Department of the CEZ plant in Valleyfield.
February 9-16, 1987	Consultation at Texas Instruments.
March 31, 1987	CANMET's symposium on expert systems.
July 1987	Expert system prototype delivered to CEZ in Valleyfield for assessment of the knowledge.
August 7, 1987	Letter from CEZ announcing the modernization project.
October 9, 1987	Co-ordination meeting for the new approach to be adopted for the expert system following the modernization project.
October 1987	Validation of the prototype by the director of hydrometallurgy, metallurgical enginners, foreman and operators
November 6, 1987	End of project meeting at CEZ.
March 29, 1988	Presentation of study report in Ottawa.

2) INITIAL GOAL OF THE PROJECT

The initial goal of the project was to show the possibility of assessing an expert system used for process control and also to develop Canadian expertise in this field.

3) SEARCH FOR A PLANT HAVING THE DEVELOPMENT CRITERIA

It is common procedure to obtain operating knowledge and expertise for the modernization or expansion of a plant. The use of an expert system makes it possible to keep, model and formalize the data thus obtained.

Lavalin carried out numerous computerized industrial supervision studies and projects in 1985. Two of these studies could have good potential for the implementation of an expert system:

- the Aluminerie de Bécancour (ABI), for technology transfer;

- Canadian Electrolytic Zinc (CEZ), for operator assistance.

CEZ was the plant chosen. It was decided to incorporate the expert system into the planned automation of the hydrometallurgy operations. It could be linked to the process control system so that the expert system's knowledge base would be constantly updated.

LAVALIN's automation group, had already studied certain commercially available software packages and developed a breakdown assistance prototype for a Merlin-Gérin programmable controller.

4) THE PARTIES INVOLVED

The parties involved in the pilot project for an expert system used for process control are:

CANADIAN ELECTROLYTIC ZINC, a subsidiary of the NORANDA Group. In 1987, CEZ produced 230,000 tonnes of zinc and 430,000 tonnes of sulphuric acid, employing more than 750 persons.

CANMET Canada Centre for Mineral and Energy Technology), an organization whose main role is to highlight the importance of minerals and energy in the Canadian economy through research and development activities regarding the mining industry, mineral processing, and the use of metals, industrial minerals and fuels.

Since 1907, researchers at CANMET have been studying and perfecting methods for safer and more efficient extraction, processing and use of Canada's energy and mineral resources. Through these efforts, CANMET achieves its three main objectives:

- to provide the Minister with data to be used in drawing up policies regarding non-renewable resources;

- to serve the government's social objectives regarding health, safety and the environment;

- to help industry with its R&D operations in order to improve its economic performance and productivity.

LAVALIN, an international firm working in the fields of design-engineering-construction. The Group had some 7,000 employees as at December 31, 1986.

5) DEVELOPMENT

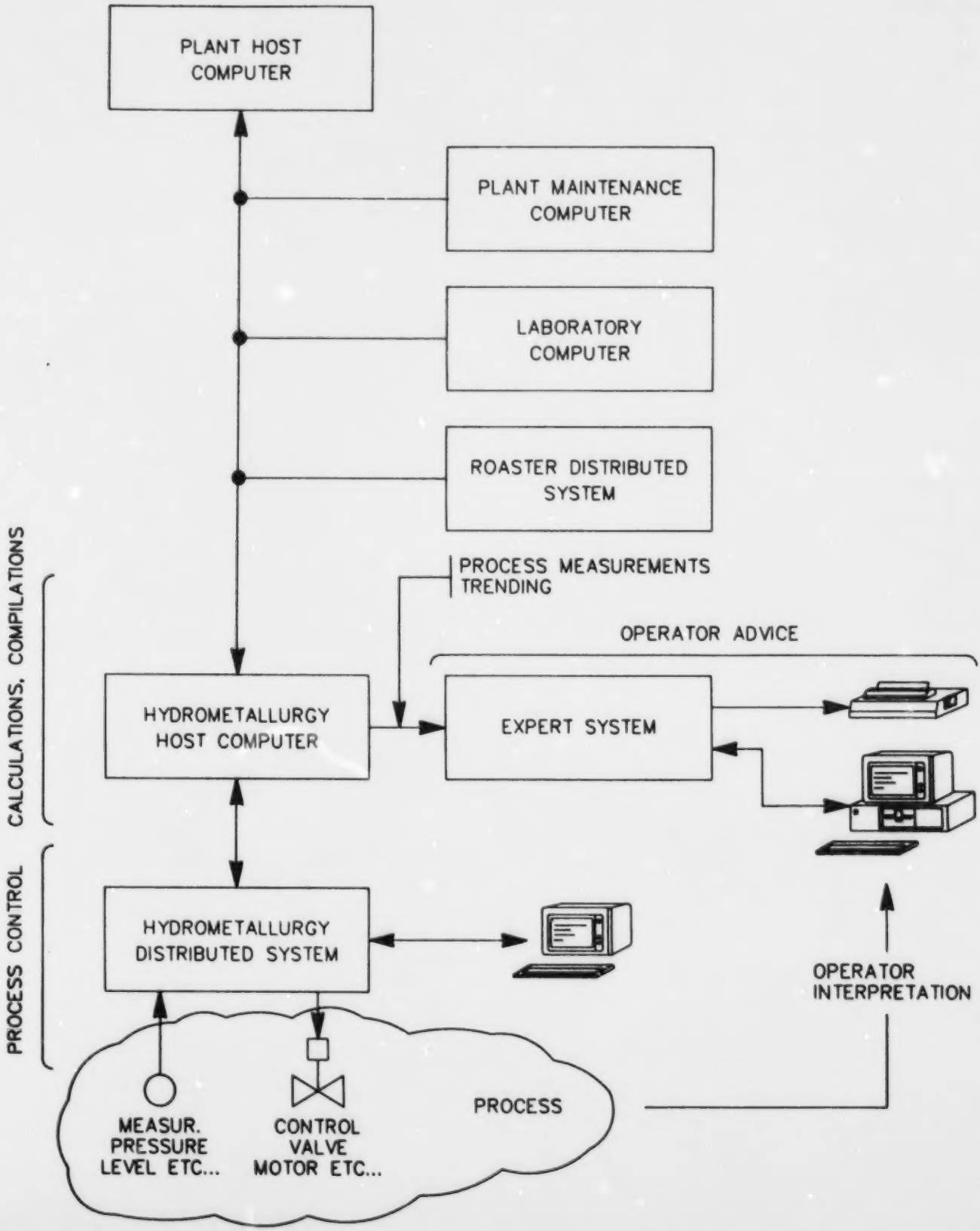
The development of the expert system began with the creation of the joint team in November 1986. The different participants were assigned to the following committees:

- project management;
- knowledge engineering;
- computer equipment and software packages;
- ergonomics.

Various scenarios were drawn up regarding the approach to be taken for developing the system and obtaining the knowledge.

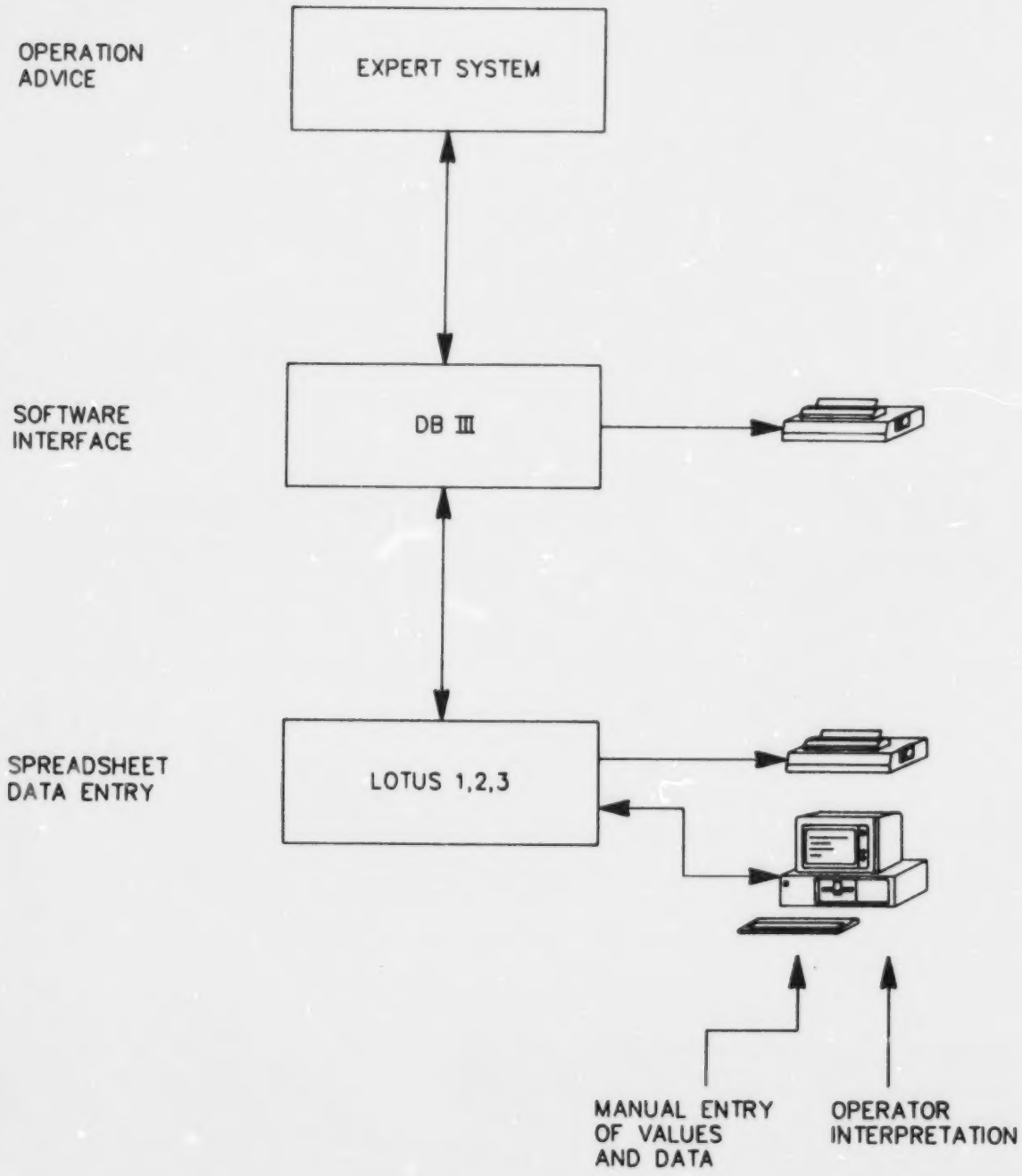
EXPERT SYSTEM

PREVIOUS COMMUNICATION NETWORK FOR DATA ENTRY



EXPERT SYSTEM

SINCE THE DISTRIBUTED SYSTEM WASN'T IMPLEMENTED UNDER SCHEDULE FOR THE EXPERT SYSTEM PROJECT, DATA ENTRY WAS MANUAL.



Several software packages were evaluated from the point of view of use and cost. These were:

- INSIGH II;
- ESP ADVISER;
- OPS83;
- FLOPS;
- PICON;
- PC PLUS.

The following computers were also evaluated from the point of view of operating speed and cost:

- IBM-XT;
- IBM-AT;
- OGIVAR 80386;
- COMPAQ 386.

Based on these evaluations, it was decided to use Texas Instruments' Personal Consultant Plus software on a COMPAQ 386 computer.

We went to Texas Instruments in February 1987 to have consultation about using the PC PLUS program properly.

The knowledge engineering began with research allowing us to understand the process and the hierarchical operation of the production unit and the operating methods. This knowledge was used to develop a model, which was presented at the symposium on expert systems used in the mineral industry held in Ottawa in March 1987.

Following discussions with the operating staff, it was decided to develop two knowledge systems. The first system was designed to help the operator by assessing the Hydrometallurgy production parameters and making recommendations based on these parameters. The second system gives the operator and management an overall idea of the state of the process.

The modernisation project was not approuved at this date.

It was no longer possible to update the data automatically, it was decided to use the Lotus 1-2-3 spreadsheet program for manual entry.

A spreadsheet was developed which was an exact reproduction of the production report sheets. This achieved the objective of ensuring the continual updating of data, without increasing the operator's workload.

The expert system with its data input spreadsheet was studied from a functional point of view, and the knowledge base was checked by the expert. Once it was certain that the expert system was operating correctly, it was installed in an IBM PC-AT compatible micro-computer and delivered to CEZ in July 1987 so it could be validated and knowledge added.

At the beginning of August 1987, the decision was made to modernize Hydrometallurgy. There followed a period of reflection on the future of the project and on the technical implications of this decision.

After studying the alternatives, it was decided to stop developing the knowledge for the following reason:

- In our opinion, the knowledge developed should reside in the distributed system for the rules using purely arithmetical calculations and continue to reside in the expert system for the others. Moreover, the addition of a distributed system would make it possible to modify the conventional control strategies and increase the precision of the controls. This would necessarily influence the operating recommendations and possibly the rules of the expert system.

It was also decided to complete the evaluation of the prototype delivered to CEZ by having its knowledge validated by the head of Hydrometallurgy, the metallurgical engineers and the operators.

The prototype was installed on computer at the CEZ plant, and valided by the following personnel:

- the director of hydrometallurgy
- the metallurgical engineers
- foreman
- operator

The main comments retained from this experience are as follows:

Reaction of management

1. Favourable reaction and surprise regarding the detail and relevance of the messages issued by the system
2. Favourable reaction regarding the exactitude of the reasoning
3. The knowledge covered by the validation test is very limited

Reaction of the process engineers

1. Agreement with management reactions
2. Appreciated quality of the messages
3. Interface with user should be more elaborate and diversified

Reaction of the foreman and operator

1. Enthusiastic reception; expressed wish for rapid deployment
2. Tended to favour the expert system over a conventional automatic control system
3. Unsuccessful attempts to outwit the system by entering unrealistic values

Other comments

When it was explained to the operators that their knowledge would be required to improved the system, they developed a tool somewhat like a memory aid.

Data enty by an electronic form is considered heavy and dull.

The level of complexity of the test was insufficient to result in technical problems that the system would have resolved.

6) CONCLUSION

We can conclude that the objectives set for the development of this project were achieved since the initial goals of the project were not only attained but exceeded, and at a cost well below the estimated cost of the project. The project achieved, among others, the following goals:

- It was shown to be possible to develop an expert system to be used in process control.

- The expertise was developed at Lavalin Pancanadian company. Before starting the project, the expert system appeared to be a miracle product capable, among other things, of synthesizing human thought.

- The realization of this pilot project enabled us to discover that it is a good tool for some tasks like operation help, electronic instruction manual, etc. However, knowledge acquisition remains the principal problem when developing the project. That knowledge should not be common knowledge but has to be knowledge from one or many experts.

  Once knowledge is acquired, an important step is accomplished since the knowledge is diffused whether or not it becomes part of an expert system.

- A methodology for research and formalization of the knowledge was acquired (see Appendix A).

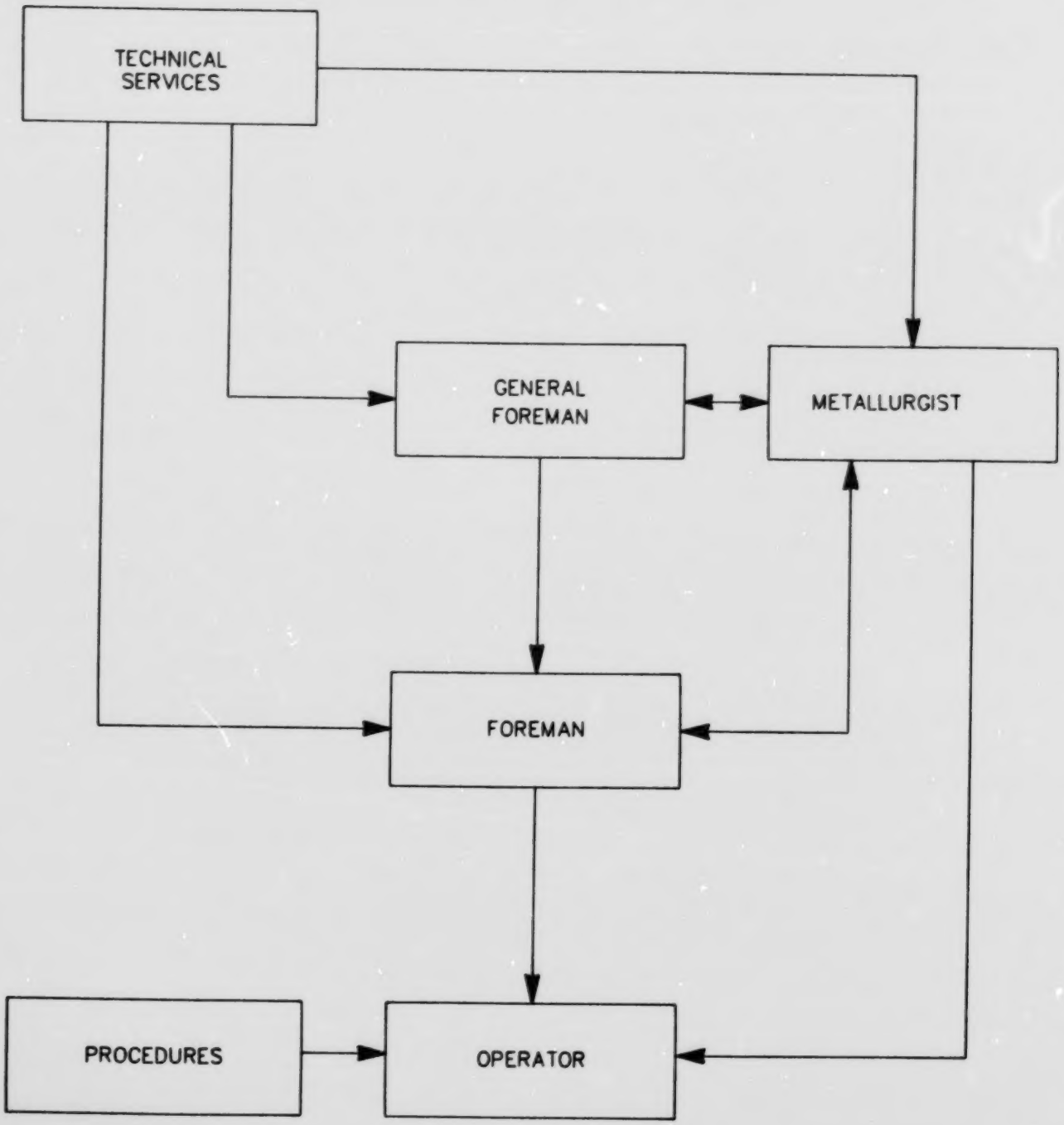
- The possibility of developing an expert system using simple, inexpensive software with a microcomputer was demonstrated (the cost of the software is less than $5,000.00 and of the microcomputer less than $10,000.00). The software used interfaces with DBIII, enabling various interfaces and uses.

- Basic development rules were established regarding what should be done and what should not be done. Most important is to have an expert available who must be assigned full time to the project during the development and expertise validation phases. The validation committee must also be available during the validation phase.

- This new technology helped demystified by developing an expert system and adapting it to an industrial environment.

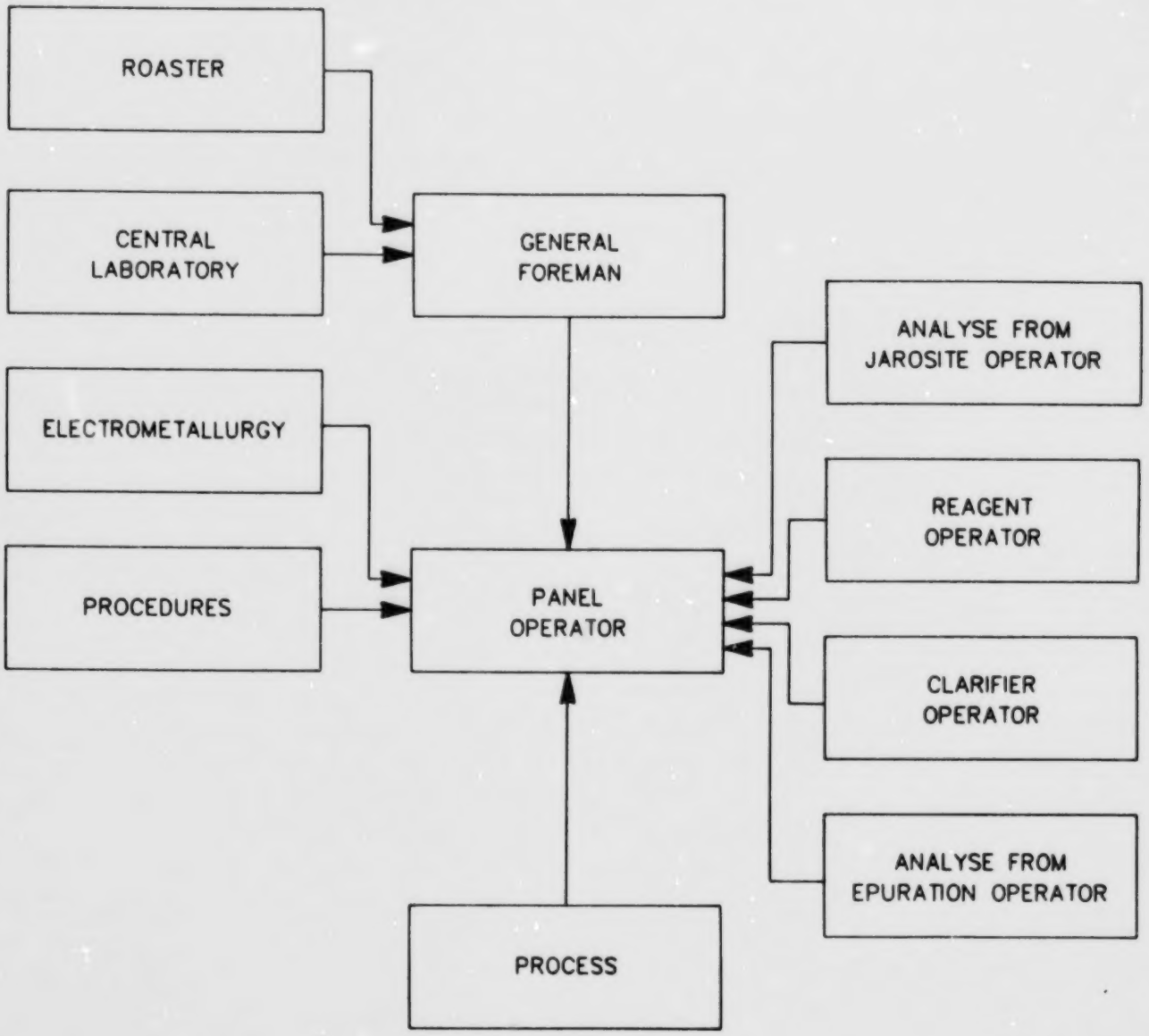
APPENDIX A

FLOW OF EXPERTISE



APPENDIX A

INPUT DATA TO THE LEACH CONTROL PANEL OPERATOR



APPENDIX A

KNOWLEDGE ENGINEERING

Obtaining the knowledge

Knowledge engineering as used in this report concerns obtaining knowledge from experts, as well as formalizing it in the form of rules.

We tackled the topic of knowledge engineering by looking for advice and suggested methods in our books and journals. Since we were unable to find anything relevant to our project, we proceeded as follows:

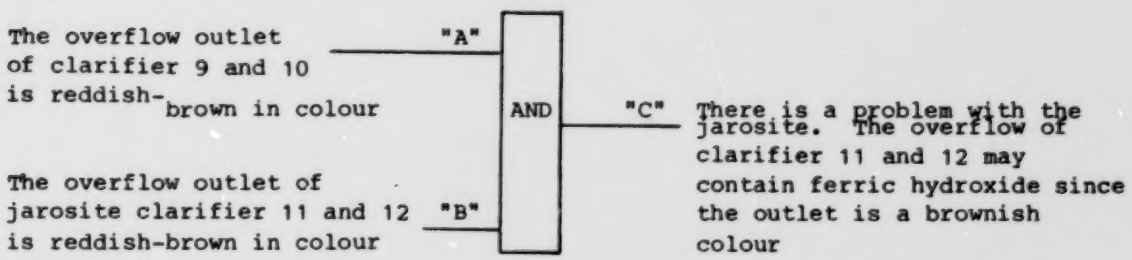
- The expert described to us the process and its control methods. We then obtained the flow sheets and main parameters for the process from CEZ. After studying these documents, we went to the plant to learn how the process worked. We also noted the terms used by the operators so that the same terms would be used in a consultation of the expert system.
  In our opinion, a thorough knowledge of the process and operation is needed to understand the expert's jargon and follow his thinking.

  The first sessions with the expert were tape-recorded and the tapes were later listened to and transcribed. We quickly found that this method of obtaining the knowledge was time consuming and difficult since it was

extremely difficulte, if not impossible, to derive formal rules from the texts.

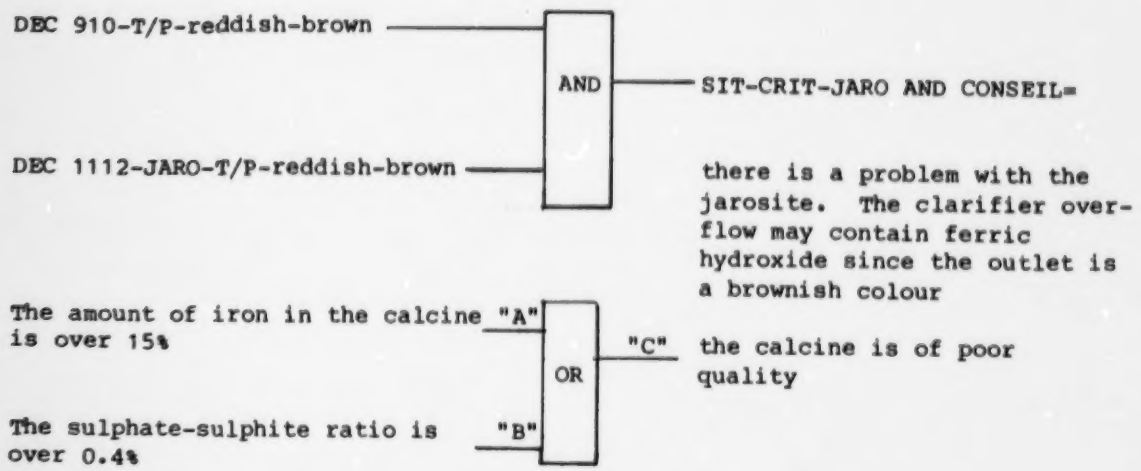
After much trial and error, the two knowledge engineers working on the project adopted two different methods.

The first method, which was utilized for the CEZ04 data bank, used representation through standard IEEE and ANSI logical diagrams. The representation below is symbolic.


The overflow outlet of clarifier 9 and 10 is reddish-brown in colour
"A"
The overflow outlet of jarosite clarifier 11 and 12 is reddish-brown in colour
"B"
AND
"C"
There is a problem with the jarosite. The overflow of clarifier 11 and 12 may contain ferric hydroxide since the outlet is a brownish colour

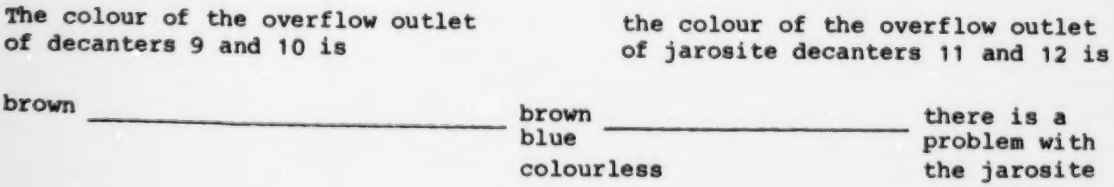
This representation signifies that the two statements "A" and "B" must be accurate and true for "C" to be true.

During the sessions with the expert, the knowledge was directly represented following the same schematic but often in its programmable form.


DEC 910-T/P-reddish-brown
DEC 1112-JARO-T/P-reddish-brown
AND
SIT-CRIT-JARO AND CONSEIL=
there is a problem with the jarosite. The clarifier overflow may contain ferric hydroxide since the outlet is a brownish colour
The amount of iron in the calcine is over 15%
"A"
The sulphate-sulphite ratio is over 0.4%
"B"
OR
"C"
the calcine is of poor quality

This representation signifies that one or both of the statement "A" and "B" must be accurate and true for "C" to be true.

The second method, which was utilized for the CEZ05 data bank, uses the following representation:


The colour of the overflow outlet of decanters 9 and 10 is
the colour of the overflow outlet of jarosite decanters 11 and 12 is
brown
brown
blue
colourless
there is a problem with the jarosite

The representation used in the second method describes an association between two parameters without specifying whether this association is "AND" or "OR".

Validation of the knowledge

We used two methods for validating the knowledge. From the beginning of the project, the rules were programmed and the validation was carried out directly by computer. This method has the advantage of allowing the expert to rapidly see the final product of his expertise and its presentation to a user.

However, this method is time consuming since each adjustment or modification of the knowledge alters the program, with all that involves.

CEZ04 "Leaching operation" data base

Later on, the knowledge was obtained and formalized in the form of logical diagrams and then validated by the expert. Since the later was not familiar with the system of symbols, knowlege engineer translated it orally for him into words. At that stage, the knowledge remained on paper since subsequent additions of knowledge modified either certain rules or their organization or execution. In conclusion, it seems easier to program everything all at the same time once the expert's knowledge has been obtained and validated.

CEZ05 Data Bank

After the expert's knowledge was obtained and validated on screen by the operator, programming continued for the CEZ05 data bank.

APPENDIX B

1.0 "OVERALL PERFORMANCE" KNOWLEDGE BASE CEZ05

The knowledge base used to assess the overall performance of Hydrometallurgy is contained in the CEZ05 files.

1.1 Objectives

The main objective of this knowledge base is to give operators and management personel a general view of the process (see Appendix E).

1.2 Current state

In its current state, this knowledge base has only partly achieved its objectives. For the moment, it only contains knowledge regarding the volumes.

It assesses the production situation at the plant based on the total power consumption. The amperage used by electrolysis is a good indication of productivity. A large decrease in power consumption is a signal that production at the plant is below normal and the cause of the problem has to be found.

The expert system can thus determine if the plant is in a shutdown situation, whether planned or not, if set points have not been transmetted to the operator. If there is a shutdown, the system displays user recommendations to the operator.

Of course, it is also possible that the decrease in power consumption is due to problems not intrinsic to the processes themselves (open circuit breaker, breakdown in the Hydro-Québec network, etc.).

After assessing the quality of the solutions (concentrations, pH, etc.) and the volume of the process solution inventories stored in the plant, it must be determined whether or not the pumping between the different sections of the plant should be modified.

Recommendations regarding the production and pumping rates as well as a note explaining the reasons behind each of these decisions are displayed to the operator.

1.3 Knowledge source

The source of the knowledge is the expertise of the Hydrometallurgy Department's metallurgical engineer.

1.4 Structure

This knowledge base uses only one frame, called "Usine". It will be possible to create small frames later on if needed.

The rules are classified according to their role to form rulegroups. The different rule groups are:

Action: Process knowledge rules which are directly used for advising the operator what decisions to make. They include many forward chaining rules which are fired when an intermediate parameter or variable is defined. It is this group which contains the heart of the knowledge. (27 rules)

Example:

```
RULE054 [ACTION-RULES]
-------
If   1)  1) The total inventory in impure solution in the leach is TROP_BAS,
            or
         2) The total inventory in impure solution in the leach is BAS, or
         3) The total inventory in impure solution in the leach is NORMAL, and

     2)  1) The total inventory in electrolyte solution to electrolysis is
            HAUT, or
         2) The total inventory in electrolyte solution to electrolysis is
            TROP_HAUT,
Then 1) it is definite (100%) that The pumping of the electrolyte between the
        electrolysis and the leach is AUGMENTER, and
     2) it is definite (100%) that The decision to take is
        AUGMENTER_POMPAGE_ELECTRO_LIX.


IF: INVEN_TOT_IMPURE = TROP_BAS OR INVEN_TOT_IMPURE = BAS OR INVEN_TOT_IMPURE
    = NORMAL AND INVEN_TOT_ELECTRO = HAUT OR INVEN_TOT_ELECTRO = TROP_HAUT
THEN: POMPAGE_ELECTRO_LIX = AUGMENTER AND DECISION =
      AUGMENTER_POMPAGE_ELECTRO_LIX

PREMISE:  ($AND
            ($OR
              (SAME FRAME INVEN_TOT_IMPURE TROP_BAS)
              (SAME FRAME INVEN_TOT_IMPURE BAS)
              (SAME FRAME INVEN_TOT_IMPURE NORMAL))
            ($OR
              (SAME FRAME INVEN_TOT_ELECTRO HAUT)
              (SAME FRAME INVEN_TOT_ELECTRO TROP_HAUT)))
ACTION:  (DO-ALL
           (CONCLUDE FRAME POMPAGE_ELECTRO_LIX AUGMENTER TALLY 100)
           (CONCLUDE FRAME DECISION AUGMENTER_POMPAGE_ELECTRO_LIX TALLY 100))
```

Compare: These rules are used to make comparisons between parameters and numerical values. Basically, they are used to describe intermediate parameters used subsequently by other rules (8 rules).

Example:

RULE024 [COMPARE-RULES]

If 1) The temperature of the electrolyte at the outlet of the electrolysis tanks of hall 1 (in deg. C) is greater than or equal to 0, and
2) The temperature of the electrolyte at the outlet of the electrolysis tanks of hall 1 (in deg. C) is less than 38,
Then it is definite (100%) that The temperature of the electrolyte at the outlet of the electrolysis tanks of hall 1 is BASSE.

```
IF: VALUE T_ELECTRO_HALL1 >= 0 AND VALUE T_ELECTRO_HALL1 < 38
THEN: TEMP_ELECTRO_HALL1 = BASSE

PREMISE:  ($AND
            (GREATEQ$
              (VAL1 FRAME T_ELECTRO_HALL1) 0)
            (LESSP$
              (VAL1 FRAME T_ELECTRO_HALL1) 38))
ACTION:  (DO-ALL
           (CONCLUDE FRAME TEMP_ELECTRO_HALL1 BASSE TALLY 100))
```

Usine: This group contains general usage rules that apply to the entire plant or consultation. This is where knowledge regarding the overall operating context is found. The rules controlling the calling of external programs or read/write operations in external files are also found here. The operations which take place at the end of a consultation, such as the display of recommendation messages, are fired by rules belonging to this group. (28 rules)

Example:

```
RULE010 [USINE-RULES]
--------
If   1) The actual status of the amperage is consumed at the plant is
        TROP_BAS, and
     2) The status of the plant supply of electricity by Hydro-Quebec is
        ARRET_NON_PLANIFIE,
Then 1) it is definite (100%) that The operating context of the plant is
        ANORMAL, and
     2) it is definite (100%) that The major source that causes the context
        is HYDRO-QUEBEC.

IF: E_AMP_ACTUEL = TROP_BAS AND ETAT_HQ = ARRET_NON_PLANIFIE
THEN: CONTEXTE = ANORMAL AND SOURCE_MAG_PROB = HYDRO-QUEBEC

PREMISE:  ($AND
            (SAME FRAME E_AMP_ACTUEL TROP_BAS)
            (SAME FRAME ETAT_HQ ARRET_NON_PLANIFIE))
ACTION:  (DO-ALL
           (CONCLUDE FRAME CONTEXTE ANORMAL TALLY 100)
           (CONCLUDE FRAME SOURCE_MAG_PROB HYDRO-QUEBEC TALLY 100))
```

Check: Each parameter read by the expert system which comes from outside the system (data banks via reports) must be validated. There are two types of validating and checking rules. Some of these rules check only one parameter at a time (e.g. an analog value compared with a range of acceptable values), while others check the cohesion of a group of parameters (e.g. the operating status of a series of reservoirs, knowing that at least four of them should be in operation) (48 rules)

The variables were created to represent explicitly, among others, an operating parameter (e.g. the concentration of zinc in a given solution), an equipment status (e.g. the operating or isolated status of a reservoir) or an intermediate state corresponding to a physical state of the process or part of the plant (e.g. the total inventory of impure solution).

A total of 135 parameters have been defined to date, 80 of which were obtained from the data base.

Example:

```
RULE094 [VERIFIE-RULES/antecedent]
-------
If   1) The status of the thickener 6 of the 1st stage of the leach is known,
        and
     2) The status of the thickener 7 of the 1st stage of the leach is known,
        and
     3) The status of the thickener 8 of the 1st stage of the leach is known,

Then it is definite (100%) that The number of thickener 6 , 7 and 8 of the
first stage of the leach who are in operation is the result of a function
which counts the quantity of equipment in operation.


IF: STATUT_LIX_DEC6 IS KNOWN AND STATUT_LIX_DEC7 IS KNOWN AND STATUT_LIX_DEC8
    IS KNOWN
THEN: NOMBRE_DEC678_OPER = TROUVE_RES_OPER (LIST (VAL1 FRAME STATUT_LIX_DEC6)
      VAL1 FRAME STATUT_LIX_DEC7) (VAL1 FRAME STATUT_LIX_DEC8))

PREMISE:  ($AND
            (KNOWN FRAME STATUT_LIX_DEC6)
            (KNOWN FRAME STATUT_LIX_DEC7)
            (KNOWN FRAME STATUT_LIX_DEC8))
ACTION:  (DO-ALL
           (CONCLUDE FRAME NOMBRE_DEC678_OPER
             (TROUVE_RES_OPER
               (LIST
                 (VAL1 FRAME STATUT_LIX_DEC6)
                 (VAL1 FRAME STATUT_LIX_DEC7)
                 (VAL1 FRAME STATUT_LIX_DEC8))) TALLY 100))
ANTECEDENT:  YES
```

There are 20 auxiliary functions, programmed in LISP (PC Scheme dialect). Some of them control the read/write operations in external files. Others are used primarily for carrying out minor mathematical calculations such as comparing certain variables with limits and calculating solution inventories.

Some free variables have been defined. The most important of these is undoubtedly the "message" variable. It acts as a message composed of small chunks of advice, recommendations, etc. found in the rules. At the end of a consultation, the final message is displayed on the screen so the operator may read the recommendations.

1.5 Goals of the expert system

Following the reading of process data and calculation of solution inventories, the goals of the expert system during a consultation are:

1) Identify the plant's overall operating context.
2) Assess the situation regarding the pumping of the impure solution between lixiviation and purification.
3) Assess the situation regarding the pumping of the neutral solution to hall 1 and hall 2 of electrolysis.
4) Assess the situation regarding the pumping of the solution between electrolysis and lixiviation.
5) Make a decision regarding pumping.
6) Assess production at lixiviation.

7) Assess production at purification.

8) Assess production at hall 1 and hall 2 of electrolysis.

9) Make a recommandation regarding production.

10) Gather together the decisions and display them.

1.6 Tasks carried out during a consultation

The following tasks are carried out during a consultation of the CEZ05 knowledge base.

1) Write into the CEZVALD.TXT file the names of the parameters whose values are required by users to the file CEZVALD.TXT. The variable names are followed by two numeric characters representing the time (present = 00).

For example:

(STATUS-1ETAPE-RES3"00")

(STATUS-1ETAPE-RES3"20")

The first example shows the parameter for the first stage of tank 3, at the present.

The second example represents the state of the same tank, 20 hours earlier.

2) Call up the program CEZDATA.EXE. This program will retrieve the parameters states previously requested in the CEZVALD.TXT file from the process data bank and save them to the CEZVALR.RD (response) file with their confidence factors.

3) Read the requested values and confidence factors of the variables in the CEZVALR.RD file.

4) Validate each new piece of data by the forward chaining rules. If the data are doubtful, a warning giving the details of the problem is immediately displayed on the screen. A brief message will also be displayed in the user message at the end of the consultation.

5) A message will be generated for reports that were not updated. The CEZHRE.TXT file contains the data on report updating.

6) Calculate the solution inventories.

7) Identify the operating context.

8) Give a production help message.

9) Display user message.

10) Write certain parameter names and their associated values calculated during the consultation into the CEZMAJ1.TXT file.

11) Call the CEZMAJ1.EXE program.

12) Terminate consultation.

During most of these steps, it is possible to use PC PLUS's built-in consultation facilities (HELP, WHY, REVIEW, HOW, etc.).

If the confidence factor of a parameter read from the data base is too low, a question will be displayed on the screen.

Whenever a question is displayed, it will be accompanied by a choice of possible responses (if applicable). The system is provided with a range of acceptable values in order to validate the numerical responses received from the keyboard during a consultation.

If a "nil" value (in LISP "( )") is received from the user in response to a question regarding a process parameter, the expert system will use the dBASE program to take the current value of the parameter directly from the data base.

2.0 KNOWLEDGE BASE "LEACHING OPERATION" (CEZ04)

The knowledge base for evaluating the leach operation is in the files CEZ04.

2.1 Objectives

The principal objective fo this knowledge base is to advise the leach operator on how to increase productivity at the CEZ plant.

2.2 Actual state

The complete knowledge on the leach process was picked up from the expert. The knowledge base is concerned with the following processes and variables:

- rosated concentrate supply
- concentration and quality of reagents
- first stage of leaching
  - a) clarifier overflow
  - b) solids
  - c) levels
  - d) equipments

- Second stage of leaching
  - a) clarifier overflow
  - b) solids
  - c) levels
  - d) equipments
- Jarosite conversion
- Jarosite washing
- Analysis
  - a) from central laboratory
  - b) done by the jarosite operator
- Iron concentration in solution at different stages of the process
- Process state depending on colors
- Solution acidity at different stages of the process

All the knowledge described up here was formalized in the form of logical schematics that were later aproved by the expert.

The functional relationships between the different parameters and processes described before were done for:

- First stage of leaching
- Second stage of leaching
- Roasted concentrate supply
- Concentration and quality of reactants
- Laboratory analysis for roasted concentrate, for the first and second stage of leaching

The expert's knowledge programming was done only for:

- First stage of leaching
- Second stage of leaching
- Roasted concentrate supply
- Concentration and quality of reactants

Conclusion

In its actual stage, the knowledge base fulfilled the objectives only partially. This is explained by the fact that the knowledge base wasn't confirmed by a panel of experts and wasn't put to use for helping the operation.

2.3 Source of expertise

The source of expertise was mostly from the metallurgist engineer from the hydrometallurgic department. Some expertise came from operators and foremen but these were all validated by the metallurgist engineer.

3.0 EXPANSION

The future aspects that must be developped are:

1) Widening and deepening of the knowledge stored in the knowledge base.

2) Expertise validation by a panel of experts.

3) Start developping exchanges between the files CEZ04 and the data bases of the management computer of the electrometallurgy and also with the distributed control system. It is noteworthy to mention that data is already sent partially to the software DBIII.

4) Continue linking the two bases to each other.

5) Study the new version of Texas Instruments' PC PLUS program specifically designed for interactive graphic displays and process control.

6) Study the method for transferring the distributed control system for hydrometallurgy.

7) Review the knowledge installed in the plant by comparing it with the new process command strategy introduced by the distributed control system project.

Description of a distributed system

A distributed system is a computerized control system with various functions such as control loops, trends calculation, variable recording, etc. It is called distributed, in contrast with a centralized system. Control is decentralized in multiple local-mounted cabinets and the central control panel is used only for operator interface.

4.0 CONCLUSION

With the expert system as it stands now, the knowledge bases are starting to be a tool are worth evaluating thoroughly from the point of view of content (validation of rules and knowledge) and use.

We have developed enough knowledge to allow us to judge the use of this software in industrial applications.

It is easier to realize than a software program to do certains tasks such as:

- logical functions
- values comparison

It is easy to visualize the working rules and to modify them.

In our opinion, it is a promising tool that will be in a couple years, as common as word processing.

Linked with other software, its use seems very promising because it widens its field of application.

It is not a miracle tool as praised at its beginning, it is only a software.

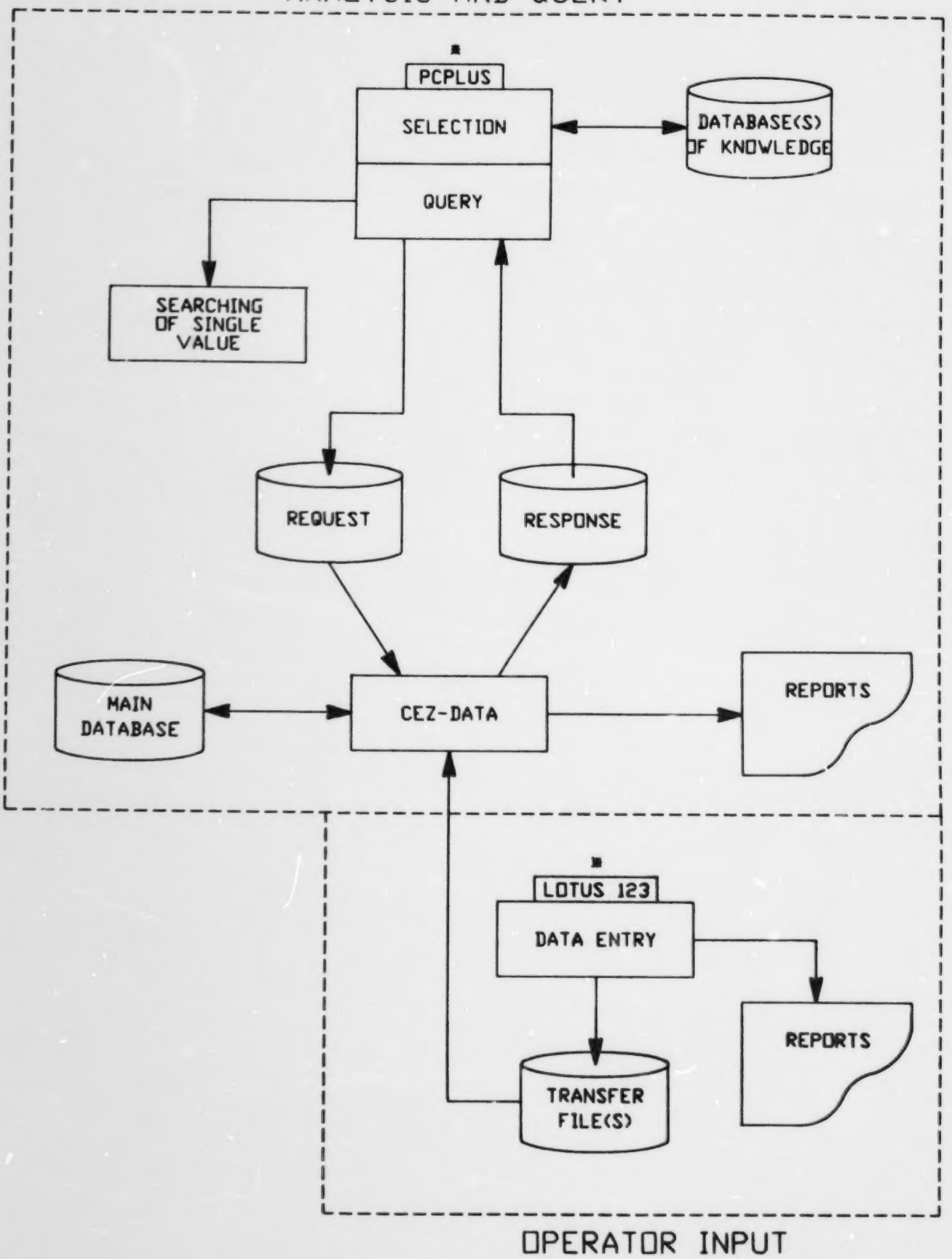
The development of an expert system remains linked to the acquisition of knowledge from one or many experts, it follows that their low availability might hinder its development.

The development of a good expertise result in a relatively big cost in manpower, this can have a negative effect on the market of expert system in development.

A return on investment is not always sure. A study must be done for that purpose when a model is developed.

APPENDICE C

ANALYSIS AND QUERY



APPENDICE C

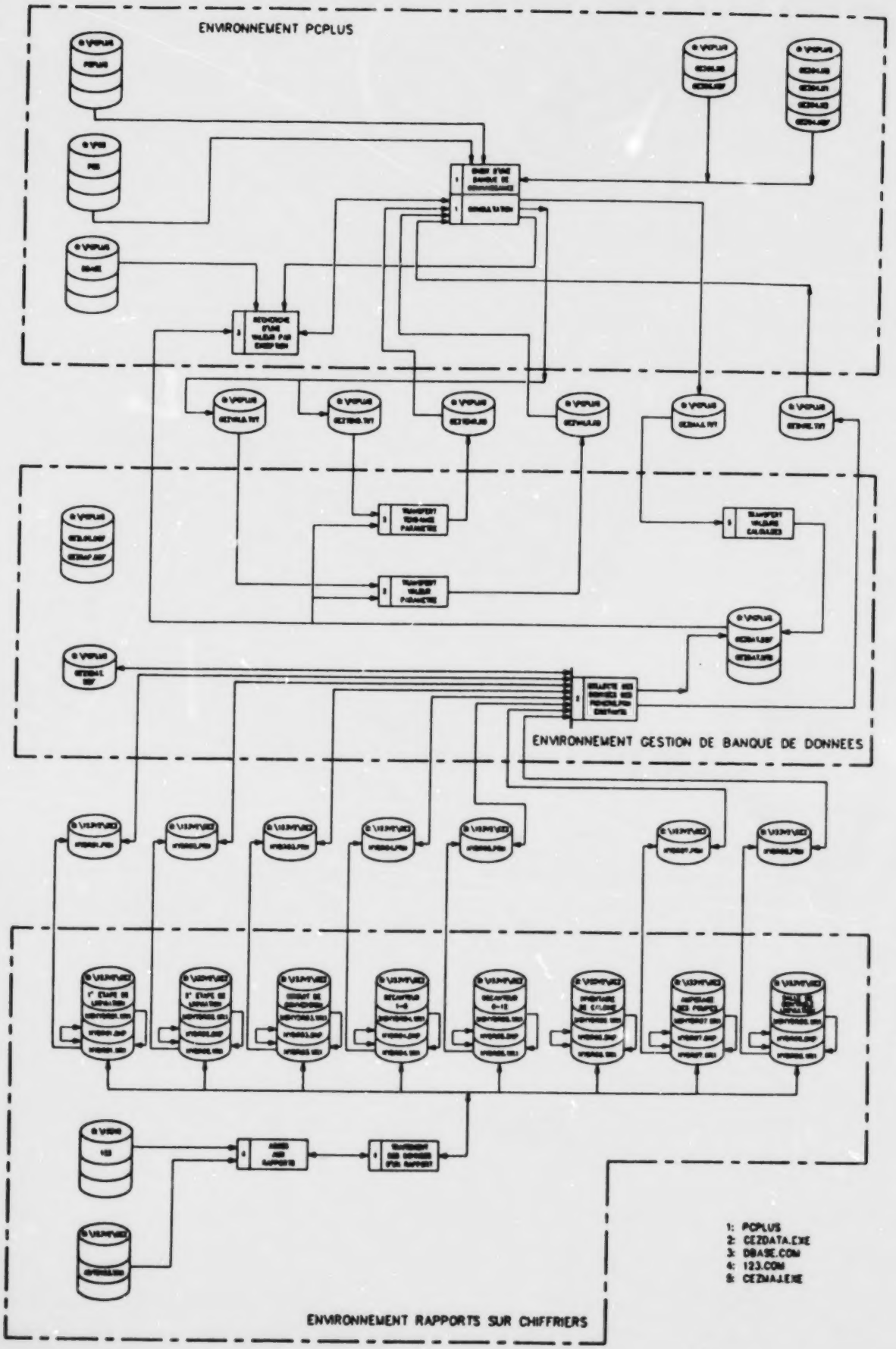


FIG. 1) ARCHITECTURE DES FICHIERS

APPENDIX C

1.0 INTRODUCTION

This support document provides information on the expert system developed for the CEZ plant in Valleyfield, and is presented in conjunction with the project study report.

The support document describes the current state of the expert system.

The software used in conjunction with the expert system (for data base management and producing operating reports) is also described.

2.0 GENERAL DESCRIPTION OF THE SYSTEM APPLICATION

The software used or developed for the hydrometallurgy project at the CEZ plant in Valleyfield was designed to:

- Capture process data;
- Print the operating reports;
- Validate the data obtained;
- Analyse the variables according to knowledge rules;
- Make user recommendations.

The expert system proper carries out the functions of validation, data analysis and displaying user recommendations. The heart of the system consists of two knowledge bases and the inference engine.

The data is basically captured from operating reports produced on electronic spreadsheets which can be printed out upon request.

A data base containing process variables serves as an intermediary between the expert system and the report spreadsheets.

2.1 Technology used

IBM PC-type microcomputers are used for this project because of their low cost, wide availability and ease of use.

These microcomputers are sturdy and some of the models are designed to withstand a harsh industrial environment.

A Compaq 386 microcomputer is used for the development of the knowledge bases to increase both the operating speed and RAM capacity.

2.2 Software used

The expert system shell is Texas Instruments' Personal Consultant Plus software.

The inference engine, which is based on the LISP language, has, among others, the following characteristics:

1) Forward and backward chaining rules;
2) Multi-value parameters;
3) Possibility of programming routines using LISP functions (PC Scheme dialect);
4) Calling of external compiled programs
5) Reading and writing of values in the data bases;
6) Confidence factors for rules and parameters;
7) Graphics.

Lotus 1-2-3 software is used for the reports, mainly because of the speed it permits in developing spreadsheets.

The data base is managed through a compiled application program.

3.0 MAIN COMPONENTS

The main components of this application are the expert system with its two knowledge bases, the management of the bank containing the process data, and the operating reports produced on electronic spreadsheets.

3.1 Expert system

3.1.1 Shell and inference engine

The Personal Consultant Plus shell consists of an inference engine based on LISP.

It is composed of two sets of files in separate directories logically linked by the DOS PATH command.

It is used not only to create and consult knowledge bases, but also to build user versions for consultation only.

These user versions can be linked by batch file commands.

3.1.2 Knowledge bases

Two knowledge bases were developed for two different purposes:

- The "Overall Performance" knowledge base (CEZ05) does a global analysis of the parameters from the three sections of the plant: lixiviation, purification and electrolysis. Its purpose is to determine whether these processes are proceeding satisfactorily and to find the source of any problems.

- The "Lixiviation Details" knowledge base (CEZ04) does a detailed analysis of the operation of certain pieces of equipment and processes involved in lixiviation. The exact source of an operating problem can be found at this level.

3.2 Data base management programs

The process parameters data base acts as a buffer between the expert system and the mass of new data coming from the process (via the operating reports).

It consists of two sorts of records: analog type parameters and logical type parameters. Each process variable constitutes a record.

The fields of this data base are used to store data on, among other things, the current value, the historical values for the last 24 hours, the trend value, the date and time of the last update and the minimum and maximum acceptable values.

For logical values, there are five fields representing the different possibilities regarding the status of a piece of equipment. The current value field is used to choose the status which applies to this piece of equipment.

Through the data base management program, it is possible to add, change or destroy records (and therefore process parameters).

Another task performed by this program consists in reading the values from the reports and transferring information between the expert system and the data base. These transfers are done through intermediate files which can be destroyed once the transfer is completed.

It is only through this program that the logical statuses can be changed. A status report can be printed out at this level.

The expert system can thus function independently of the reports through this system. For simulation purposes, the value fields can be changed and the influence of these changes on the recommendations found by the expert system can be seen soon after.

3.3 Reports produced on electronic spreadsheets

The reports entered in the system are an exact reproduction of those still used in the plant.

The reports produced by the Hydrometallurgy Department are:

- 1st step of leaching
- 2nd step of leaching
- Conversion circuit
- Clarifier No. 1 to 5
- Clarifier No. 6 to 12
- Calcine inventory
- Amperage of the pumps
- Control room - leaching

Two other reports (on reagents) were considered but not entered.

Most of these reports are completed every hour by the operator. The spreadsheets have been designed to ensure that the data is kept over a 24-hour period.

Data entered 48 hours previously, however, can be recovered at the DOS level.

3.4 File and program architecture

Figure 1 shows the transfer of information between the programs and files. This can be broken down as follows:

3.4.1 Interaction in the expert system environment

Once the operator has called the shell program and chosen the knowledge base to be consulted, the different files required interact automatically without his intervention.

The most important information transfers, as far as the application is concerned, are:

1) Call the various files in a knowledge base, including the file containing the auxiliary functions in LISP.

2) Write in file CEZVALD.TXT the names of the different process parameters whose values are required in the consultation. Also, write a number specifying which of the 24 historical values is required. "AMP-ACTUEL 00", for example, is used to identify the current value of the AMP-ACTUEL parameter (since the number is 0).

3) Enter, if necessary, the names of the different parameters whose trend is required in the CEZTEND.TXT file.

4) After the CEZDATA program is executed, read the values and confidence factors of the process parameters from the CEZVALR.RD file.

5) Read, if necessary, the values of the trends required for the process parameters in the CEZTENR.RD file.

6) Read the names of the reports and the number of minutes elapsed since the reports were updated by the operator.

7) At the end of a consultation, write in the CEZMAJ1.TXT file certain values that were calculated.

3.4.2 Interaction in the data base environment

The heart of this environment is the process parameters data base CEZDAT.DBF. This data base is controlled by two programs which are called by commands contained in the knowledge bases.

The main information transfers are:

1) Transfer information from the existing HYDROX.PRN files (X=1...8) into the CEZDAT.DBF data base.

2) Read the names of the parameters whose values or trends are

required into the CEZVALD.TXT and CEZTEND.TXT files.

3) Write the required values and corresponding confidence factors into the CEZVALR.RD file.

4) Write the required values of the trends required into the CEZTENR.RD file.

5) Transfer the calculated values of certain parameters to the data base.

3.4.3 Interaction in the reports environment

The information received from the operator is stored in different files by the macro-instructions contained in the spreadsheets. The information transfers for each report (X=1...8) are:

1) Store information in the HYDROX.WK1 file when the spreadsheet is saved.

2) Save the data from the last 48 hours (last two shifts completed) in the corresponding HYDROX.BDP file from information contained in the HYDROX.WK1 file.

3) Transfer the historical process values into the corresponding HYDROX.PRN file.

4) Reinitialize the spreadsheets when they are full from, among others, the corresponding MSHYDROX.WK1 file.

4.0 DATA BASE MANAGEMENT

Two programs, CEZDATA.EXE and CEZMAJ.EXE, manage the four data bases. These data bases are:

1) CEZDAT.DBF: This data base contains information on the process parameters. It constitutes the heart of the information sources for the expert system.

2) CEZXDAT.DBF: This data base is used to transfer data between the .PRN files produced by the report spreadsheets and the process data base.

3) CEZLOG.DBF: This base is for internal use only. It is used to define the screens displayed to the user when editing logical statuses.

4) CEZRAP.DBF: This base is used to store information on the configuration of hourly or daily operating reports. After this base was developed, the reports were replaced by those done on electronic spreadsheets. The configuration of daily reports, however, is incomplete but it is possible to complete the configuration using the CEZDATA program menus.

4.1 CEZDAT data base

This process parameter base is updated both by the CEZDATA program using data from the reports and by the CEZMAJ program with data calculated by the expert system during a consultation.

Each record contained in this base is related to a process parameter. The description of these fields is as follows:

1) VARIABLE: Contains the name of a parameter so as to link the expert system and the data base.

2) VALEUR: For analog parameters, this field contains the value of the parameter. The units of the value are specified in the description. It also contains the number of the status applicable to a logical parameter.

3) TENDANCE: Contains the numerical value of the parameter trend, expressed in engineering units/hour.

4) TEMPS: Obsolete field.

5) FACT_CONF: Field used to store the certainty factor of the parameter value. A value of 100 means that the value is certain, while a value of 0 means that the value is uncertain.

6) METHODE: Field used to identify the information source, i.e. the area of the plant where the parameter is quantified or measured.

7) FTYPE: Used to characterize the type of value stored (instantaneous, cumulative, etc.).

8) TYPENT: Used to identify the type of record, i.e. logical (choice of five possible statuses) or analog.

9) VAL_DEFAUT: When a new parameter is being defined, it is possible to define a default value.

10) VALEUR_MIN: Minimum value of the acceptable range for the value of a parameter.

11) VALEUR_MAX: Maximum value of the acceptable range for the value of a parameter.

12) DESCRIP1 & DESCRIP2: Description of the parameter, area where it is measured, its engineering unit, etc.

13) DLDATE & DLHEURE: Date and time of the last parameter update.

14) VAL_CUM: Cumulative value of a parameter, if required.

15) VAL_HIS00 @ VAL_HIS23: Field containing the historical values of a parameter for the last twenty-four hours.

(16) FSTATUS1 @ FSTATUS5: Field containing the possible options for the logical parameters.

4.2 CEZDATA program

This program was created with DBIII and compiled with CLIPPER.

The first task that this program carries out is to find the transfer files from the reports (extension = .PRN). Any data contained in these files are automatically transferred into the CEZDAT.DBF data base in order to update it. To do this, the program uses intermediate files, some of which are destroyed immediately after.

The VARIABLE field, which contains the name of the parameter, serves as a pivot for this exchange.

The time and date contained in the .PRN file is decoded in order to date the data received.

In addition, the program finds the date and time in the system when it is called. It is thus possible to subtract the number of minutes which have elapsed between the creation of the .PRN file and the corresponding data transfer. This time elapsed and the name of the report are written in the CEZHRE.TXT file. This operation determines whether or not the data received are obsolete.

The trend is calculated by linear regression over the last four values.

As the .PRN files are being transferred into the data base, the number of report files, the report name, the variable name and the time of the data being transferred are displayed on the operator's screen.

The main menu is then displayed:

[1] Variables

[2] Reports

[3] Install index files

[Q] Quit

The first option is used to view and/or change the process parameters in the data base.

The second option is used to configure or print reports from the data base.

The third option is used to reorganize the indexes of the CEZDAT.DBF data base (based on the VARIABLE field) and return to the main menu.

The last option is used to terminate the CEZDATA program and return control to the expert system shell.

4.2.1 Variables

When the user presses the "1" key, another menu appears:

[1] Maintenance

[2] Capture by variable

[3] Capture by report

[4] Capture by origin of logical statuses

[Q] Return to previous menu

If option 1 is selected, a password is required (2 E C). Once the password has been checked, the configuration screen appears.

This screen is composed of two different zones. The upper part shows the following data concerning a parameter:

- its name;
- its origin;
- its type;
- a two-line description;
- for an analog value, the minimum, maximum and default values are displayed;
- for a logical value, the five possible statuses are displayed.

It is actually the contents of certain fields in the CEZDAT.DBF data base which are displayed regarding the parameter in question.

The lower part of the screen displays a submenu with the following commands.

- "Add" a new parameter to the CEZDATA.EXE data base. The variable name and type (logical or analog) are then requested. Next, the other parameters mentioned above must be entered.

- "Change" the parameter displayed. Each of the fields can then be changed. It should be noted that the VARIABLE field (containing the name of the parameter) and the type (logical or analog) cannot be changed; the parameter must be destroyed and a new one created.

- "Destroy/Recall" a parameter. It is possible to mark a parameter for destruction or to reassign it a normal status. The parameter is not erased immediately.

- "Reconstruct" the data base. All parameters (records) marked for destruction are actually destroyed and the index files are updated.

- "Next" displays the next parameter according to the alphabetical order of the VARIABLE field.

- "Previous" displays the parameter immediately preceding the current one (see "Next").

- "Quit" is used to return to the previous menu.

- "Search" immediately displays the data regarding the desired parameter without having to going through the "Next" or "Previous" sequence.

Thus, this option is used to change the parameters in the data base through preset menus (but only if the password is known!).

If the second option ("Capture by variable") is chosen in the Variables menu, the screen will display the following data for each parameter:

- the name of the variable and the origin and type of parameter;
- the description of this parameter;
- the date and time of the last update;
- the current value and its confidence factor;
- for an analog parameter, the minimum and maximum values and the trend are displayed;
- for a logical parameter, the current status and other possible statuses are displayed.

The lower part of the screen displays the following submenu:

- "Enter" is used to change the current value and the confidence factor. For an analog parameter, the new value entered will be immediately compared with the acceptable range for this parameter.

- The message "Out of range!" will be displayed if applicable. The date and time of the last update will be entered. The trend will be calculated according to the difference between the previous value and the current value divided by the time elapsed between the two updates. For a logical parameter, the current status number will be one of the predefined numbers.

Once the new values have been entered, the user is asked to either confirm the values entered or to quit, thus keeping the previous values.

- "Search" is used to find a parameter by its name.
- "Next" displays the next parameter.
- "Previous" displays the preceding parameter.
- "Quit" is used to return to the main menu.

The "Capture by report" option in the main menu can be used instead of the "Capture by variable" option to change data in the data base.

The program then requests the report number. If the report has not been predefined, the parameters corresponding to the items in this report are displayed on the screen according to their order in the report.

The screen also displays the same editing submenu as in the "Capture by variable" option, with the addition of the command "Report" which is used to change the report number.

The fourth option in the main menu, "Capture by origin of logical statuses", is used to change the value of the logical statuses.

A certain number of pages on the screen have been defined for each of the plant's major sections (leache, purification and electrolysis) in order to show the current status of the equipment.

The "UP", "DOWN", "PAGE UP", "PAGE DOWN", "HOME" and "END" keys, are used to change the position of the cursor and/or to change the page on the screen.

To change a status, the cursor must be moved to the status in question and the return key pressed. The corresponding "Capture by variable" page will be displayed. It is then possible to change the status of a parameter as defined above. The "Quit" key is used to return to the original logical statuses page.

4.2.2 Reports

This section deals with editing and configuring operating reports from the data base.

When this option is chosen, the screen displays another menu with the following options:

[1] Maintenance for daily reports

[2] Print daily reports

[3] Print logical status reports

[Q] Return to previous menu

Option 1 is used to define and configure daily reports whose data is taken from CEZDAT.DBF.

Thus, it is possible to configure an operating report by using the menu. This approach was developed and used at the beginning of the project, but was later abandonned because it was too complicated for operators and demanded too much work from them. These reports were replaced by electronic spreadsheets.

Option 2 prints the daily report selected by its number.

Option 3 does the same thing with the logical parameters.

4.2.3 Transfer of values to the expert system

Once this program has finished running (when "Quit" in the main menu is chosen), the CEZVALD.TXT and CEZTEND.TXT files are read in order to transfer the values and trends of the parameters to the expert system to enable it to carry out a consultation regarding the process.

The values and corresponding confidence factors are written into the CEZVALR.RD file, while the numerical trends are written into the CEZTENR.RD file.

4.3 CEZMAJ program

This program uses data from the data base which have been calculated during a consultation. The data, including the name of the parameter and its numerical value, are read from the CEZMAJ.TXT file.

The program finds the corresponding record in the CEZDAT.DBF data base and copies the value into it.

APPENDIX D

1.0 REPORTS PRODUCED ON ELECTRONIC SPREADSHEETS

The reports entered on electronic spreadsheets fulfil two purposes. First, they electronically reproduce the reports which are currently completed manually by the plant operators. And, second, they provide the expert system with regularly updated data through a process data base.

The reports considered in this project come mainly from the following four work stations:

- the Leaching control panel;
- the jarosite;
- the clarifier;
- the reagents.

The reports which have already been entered can be broken down as follows:

1) Control panel: Control room - leach
Calcine inventory
Amperage of the pumps

2) Jarosite: 1st step of leach

2nd step of leach

Conversion circuit

3) Clarifiers: Clarifiers No. 1 to 5

Clarifiers No. 6 to 12

As the expert system stands now, no reports regarding the reagents have been entered.

Two directories are used for producing the reports. The first (C:\123V2) contains the spreadsheet programs, while the second (C:\123V2\CEZ) contains the spreadsheets themselves and the corresponding files.

It should be noted that the spreadsheet program is configured so that the spreadsheet C:\123V2\CEZ\AUTO123.WK1 is called automatically by the program.

1.1 AUTO123.WK1 spreadsheet

This spreadsheet is mainly used as an access menu to call the spreadsheet for the chosen report. It is also used to request the name of the operator at a work station.

To call a spreadsheet, the cursor must be positioned on the report number and the "Enter" key pressed. It is also possible to press the key representing the first letter of the operator and the report number. The spreadsheet for the report selected will then appear on the screen.

To leave the access menu, the "Escape" key must be pressed and confirmation given.

1.2 Report spreadsheet

When a report is selected, the names of the operators concerned are automatically transferred from the access spreadsheet to the report spreadsheet. These names will be printed on the report.

The report menu presents the following options:

1) View and capture data

The report is displayed. The operator can press the arrow keys to move the cursor to a given cell on the spreadsheet. He can then key in a numerical value and press "Enter". By simultaneously pressing the "Alt" key and the letter "m", he can return to the report menu.

It should be noted that the operator can view the data for the last 24 hours but can change the data only for the last two hours.

2) Print the last 24 hours of the table

This option is used to print the report. The names of the operators on duty as well as the maximum value and the average of each column are shown.

3) Save and extract data for PC PLUS

This option saves the spreadsheet and transfers the data of certain columns (corresponding to the parameters of the CEZDAT.DBF data base) to the corresponding .PRN file.

If the operator returns to the report menu by simultaneously pressing the "Alt" key and the letter "m" an hour or more after entering the spreadsheet, this command will execute automatically before returning to the menu.

4) Open a new file

When a report spreadsheet is full (when each line has been completed), this option is used to reinitialize the spreadsheet to start a new 24-hour period.

5) Choose clarifier (11 or 12)

This option applies only to the lixiviation control room report. Since these clarifiers can be used for the same function in the process, the number of the clarifier used must be specified to properly complete this report.

(0) Save and return to main menu

This option, like option 2, saves the spreadsheet and extracts the data for PC PLUS. It also returns to the the report spreadsheet access menu.

In general, no validation of data takes place at this level. It is therefore possible to assign alphabetic characters to a cell. However, these values will be interpreted as nil, and the confidence factor will be 0 when the data are transferred to the CEZDAT.DBF data base by the CEZDATA.EXE program.

2.0 CONSULTATION OPERATION

The first operation to be carried out is to choose between printing the reports and consulting one of the two knowledge bases.

The reports must normally be updated every hour. A consultation becomes useful at this point.

If a consultation is carried out, the inference engine will try to evaluate the initial data from the chosen knowledge base. To do this, it will load the CEZDATA.EXE program. It will thus be possible to see or change the value of the logical or analog parameters.

Once the program has finished running, the values and trends will be read and analysed. The knowledge rules will be fired and the final recommendations will be displayed.

2.1 Help during the consultation

The PC PLUS program provides built-in consultation facilities to help the user during a consultation. When the "F2" key is pressed, a menu is displayed with the following options:

"Why" shows the rule or reason requiring a response to the question asked.

"How" shows the different values of a parameter and how they are assigned.

"Trace" is used to follow the operation of the program (available in the development version, but not in the user version). But on the other hand, this help was compensated by the explanations given by the operation council. Each council describes in detail what are the reasons and what results from it.

"Review" is used to change the data previously keyed in.

"Save playback file" records the data provided.

"Quit" immediately terminates the consultation.

"Continue" allows the consultation to proceed.

2.2 Validation of data

The validation of data is a feature which is found in all software programs, especially when the data are keyed in by the user.

Expert systems are no exception to this rule. The validation takes place mainly at two levels.

However, the type of validation and its method of application must be understood.

Any parameter data which are false by definition are eliminated at the outset (e.g. a nonexistent or undefined status given for a piece of equipment, or a character string keyed in when a numerical value is required or a value of 100 when a pH is requested).

There are other sorts of data which are plausible, but doubtful (e.g. a response of 1 ft for the level of solution in a reservoir which is normally full). The expert system must accept such values but warns the operator that they seem strange.

In the expert system as it stands now, no validation takes place at the report spreadsheet level, basically due to a limitation of the tool.

When the data are being transferred to the CEZDATA.DBF data base, any non-numerical values (character strings, blank spaces, etc.) are replaced by the numerical value 0, and are assigned a confidence factor of nil.

All numerical values, whether appropriate or not, remain unchanged. If the parameters in the data base are viewed, any values which do not fall within a range of predefined values are displayed with an "Out of range!" message and a beep, but the values are still transferred to the expert system.

It is therefore important to provide rules, as was done in the "Overall Performance" knowledge base, to warn the operator if certain data are doubtful or, at least, not within the acceptable range.

A numerical response keyed in by the operator during a consultation is immediately compared to an acceptable range if one is defined. The consultation will continue only if the response is satisfactory.

2.3 Obtaining a value for a parameter

If the expert system has to evaluate a parameter, it will do so using the established rules and methods. If this is impossible, a question is sent to the user. If the response is "nil", the dBASE program is loaded and takes the current value directly from the data base, if applicable.

--- SYSTEME EXPERT SYSTEM ---

VERSION : [F] Francaise / French

[A] Anglaise / English

[D] DOS

Choix / Choice :

P L A N T C E Z V A L L E Y F I E L D

M A I N M E N U

1) EXPLOITATION REPORTS

2) CONSULTATION - GLOBAL PERFORMANCE

3) CONSULTATION - DETAIL LEACH

4) RETURN TO THE PREVIOUS MENU

Select your option ?

```
A5: U [W3] '[P]                                                    READY

     A         B        C D       E        F G       H        I J       K
1                              CANADIAN ELECTROLYTIC ZINC LIMITED
2                                   HYDRO-METALLURGY
3    ********************************************************************
4                                   O P E R A T O R S
5    [P] CONTROL PANEL *[J] JAROSITE     *[D] THICKENERS   *[R] REAGENTS
6    ********************************************************************
7    NAME (PER SHIFT)  *NAME (PER SHIFT) *NAME (PER SHIFT) *NAME (PER SHIFT)
8    1 -               *1 -              *1 -              *1 -
9    2 -               *2 -              *2 -              *2 -
10   =====REPORTS======*=====REPORTS=====*=====REPORTS=====*=====REPORTS=====
11   1 -LEACH CTRL ROOM*1 -1st STAGE     *1 -THICKE. 1 @ 5 *1 -THICKE.-REAG.
12   2 -CALC. INVENTORY*2 -2nd STAGE     *2 -THICKE. 6 @ 12*2 -INVENT.BIOXIDE
13   3 -PUMPS AMPERAGE *3 -CONVER CIRCUIT*                 *   MANGANESE &
14                     *                 *                 *   CELESTITE
15   ********************************************************************
16   Depress "ESC" key to quit.
17
18   To execute a command, move to the corresponding cell
19   with the cursor keys and depress [ENTER],  Or depress
20   the first letter of the operator and the desired file number.
```

```
LEACH SECTION                PLANT   C E Z   VALLEYFIELD              26/03/88

                                  MAIN MENU

          [1]  Variables

          [2]  Reports

          [3]  Index Files Installation

          [Q]  Quit

                    Your Selection ===>
```

LEACH SECTION PLANT C E Z VALLEYFIELD 26/03/88

VARIABLES

[1] Maintenance

[2] Entry per Variable

[3] Entry per Report

[4] Entry per Origin for Logic Status

[0] Return to Previous Menu

Your Selection ===>

LEACH SECTION PLANT C E Z VALLEYFIELD 26/03/88

ENTRY PER VARIABLE

Identification : AMPERAGE_HALL1 Origin : ELECTRO Type : INS

Description : L'amperage consomme au hall 1 de l'electrolyse (en kA)

Analogic	Value		Last Reading
Minimum :	10.000		Date : 26/03/88
Maximum :	100.000		Hour : 13:08:38
Actual :	100.000	Factor : 100	Trend : -69.156

Enter [E] [E] Entry [R] Research [N] Next [P] Previous [Q] Quit

MISE EN GARDE

It seems that the reports were not filles since the last consultation with PCPLUS.

List of reports late : ()

List of report not done : (HYDRO8 HYDRO5 HYDRO2 HYDRO1)

It seems to be that the results and the advices given during the consultation can't be considered exactly because the data is not refreshed periodically.

** End - RETURN/ENTER to continue

ATTENTION

The inventory of neutral solution is to low. There is a risk of sever contamination in electrolysis.

You must STOP the pumping of neutral solution to electrolysis.

** End - RETURN/ENTER to continue

AVIS

The total solution inventory in electrolyte is to low. You must stop the pumping
between the electrolysis and the leach.

We have conclude that in this case, we have obtained a bad depositof zinc at the
electrolysis. We are now obliged to reduce the course.
** End - RETURN/ENTER to continue

What is the status of the supply of the plant electricity by the network of Hydro-Quebec ?

NORMAL
ARRET_PLANIFIE
ARRET_NON_PLANIFIE

1. Use the arrow keys or first letter of item to position the cursor.
2. Press RETURN/ENTER to continue.

Are we presently in a shutdown of the process planed by CEZ ?

YES
NO

1. Use the arrow keys or first letter of item to position the cursor.
2. Press RETURN/ENTER to continue.

The opinion give by the expert system about the global situation of the process
is following:

Attention to the risk of contamination in l'electrolysis!!!!

INVENTORY

SOLUTION IN THE LEACH	: NORMAL
IMPURE SOLUTION	: NORMAL
SOLUTION IN PURIFICATION	: NORMAL
PURIFIED SOLUTION (NEUTRAL)	: TROP_BAS
ELECTROLYSIS SOLUTION	: TROP_BAS

There is an unusual situation thus the total amperage consumed in the plant is to low.

The plant must operate in a context of shutdown planified.

The advice of usage that apply in this case are :
** More - RETURN/ENTER to continue

1) Be aware to
decreasing the addition of reagent
2) Reduce the washing by decreasing the rate of pumping the solids to the basin.
3) Recycle the solids in the conversion circuit of jarosite.

PUMP RATIO

The inventory of neutral solution is TROP_BAS . The inventory of electrolyte solution is TROP_BAS . The pumping of neutral to the hall 1 of electrolysis must ARRETER .

The pumping of neutral to the hall 2 of electrolysis must ARRETER . The inventory of electrolyte solution is TROP_BAS . The inventory of impure solution is NORMAL . The pumping from the hall 1 of the electrolysis to the leach must ARRETER .

** More - RETURN/ENTER to continue

solution is TROP_BAS . The pumping of neutral to the hall 1 of electrolysis must ARRETER .

The pumping of neutral to the hall 2 of electrolysis must ARRETER . The inventory of electrolyte solution is TROP_BAS . The inventory of impure solution is NORMAL . The pumping from the hall 1 of the electrolysis to the leach must ARRETER .

LEVEL OF PRODUCTION

The zinc concentration in the electrolyte solution of the hall 1 is to low. The temperature of the electrolyte of the hall 1 is to high. You must continued to operate with REDUCE amperage in hall 1 of the electrolysis.

The zinc concentration in the electrolyte solution of hall 2 is too low. You must continued to operate with REDUCE amperage in hall 2 of electrolysis .

** End - RETURN/ENTER to continue

Consultation terminated !

Commands:

CONTINUE
HOW
PRINT CONCLUSIONS
REVIEW
SAVE PLAYBACK FILE
QUIT

Consultation terminated !

How:

Yes

- the demand of the value from process is made
- the demand of the tendency of the variable from process...
- the total amperage consume by the electrolysis of the h...
- the total amperage consume by the electrolysis of the h...
- The actual amperage consume by the plant (in AMP)
- the nominal current of the plant is (in AMP)
- The zinc concentration in hall 1 of electrolysis (in gr/l)
- The zinc concentration in hall 2 of electrolysis (in gr/l)
- The temperature of the electrolyte at the outlet of the...

1. Use arrow keys or first letter of item to position cursor.
2. Select all applicable responses.
3. After making selections, press RETURN/ENTER to continue.

```
Consultation terminated !

 the total amperage consume by the electrolysis of the hall 2 is (in KA)

 Determined to be:   40.
  ... by using  RULE006

 If    1) the demand of the value from process is made, and
       2) the demand of the tendency of the variable from process is
          made,
 Then  1) Inform the user of this decision, and
       2) call a DOS program named cezdata.exe, and
       3) Inform the user of this decision, and
       4) read data from the file CEZVALR, and
  ** More - RETURN/ENTER to continue
```

APPENDIX E

PROCESS

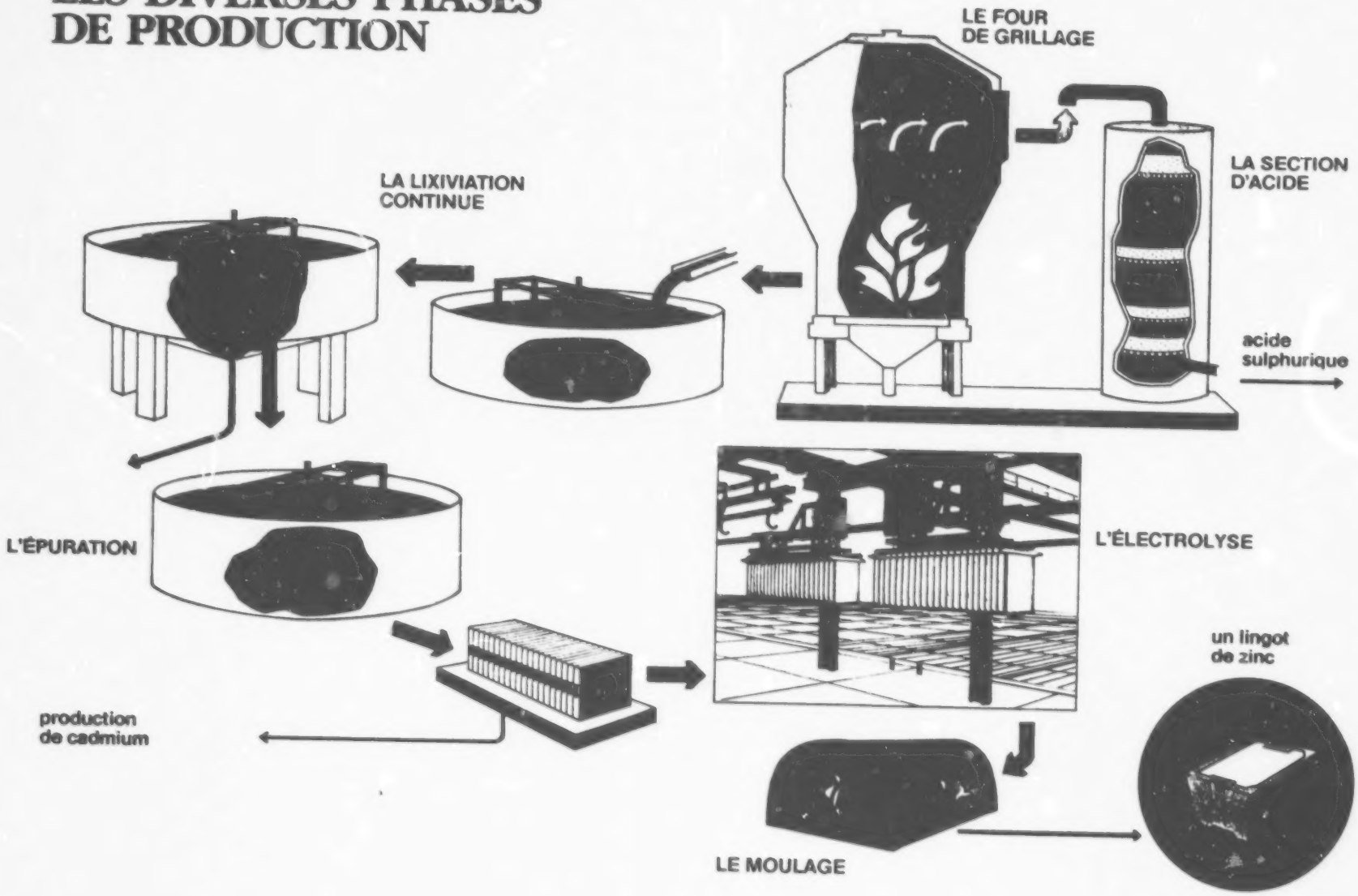
- The production phases
- Leach calcine feed
- Neutral leach stage 1

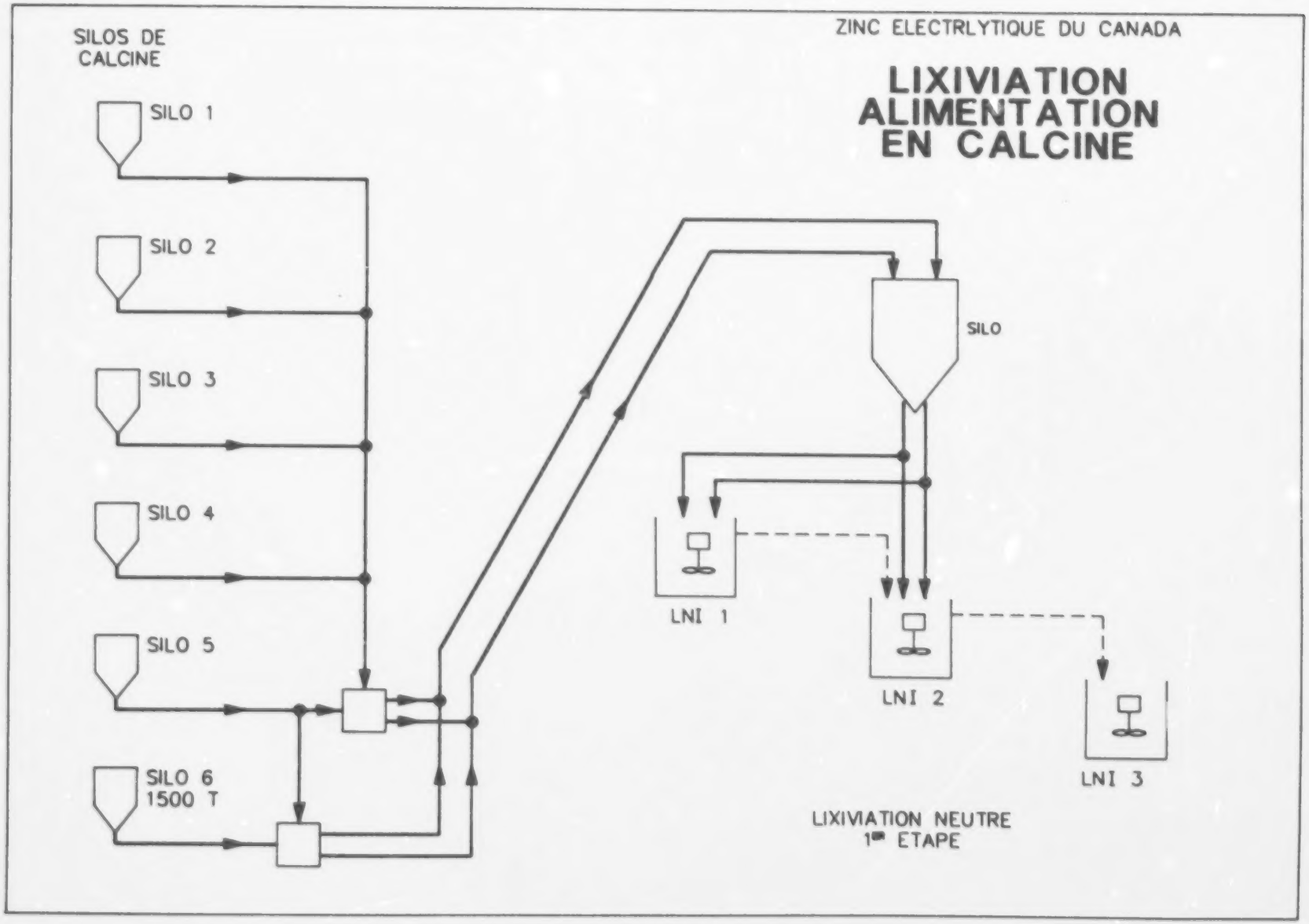
APPENDIX E

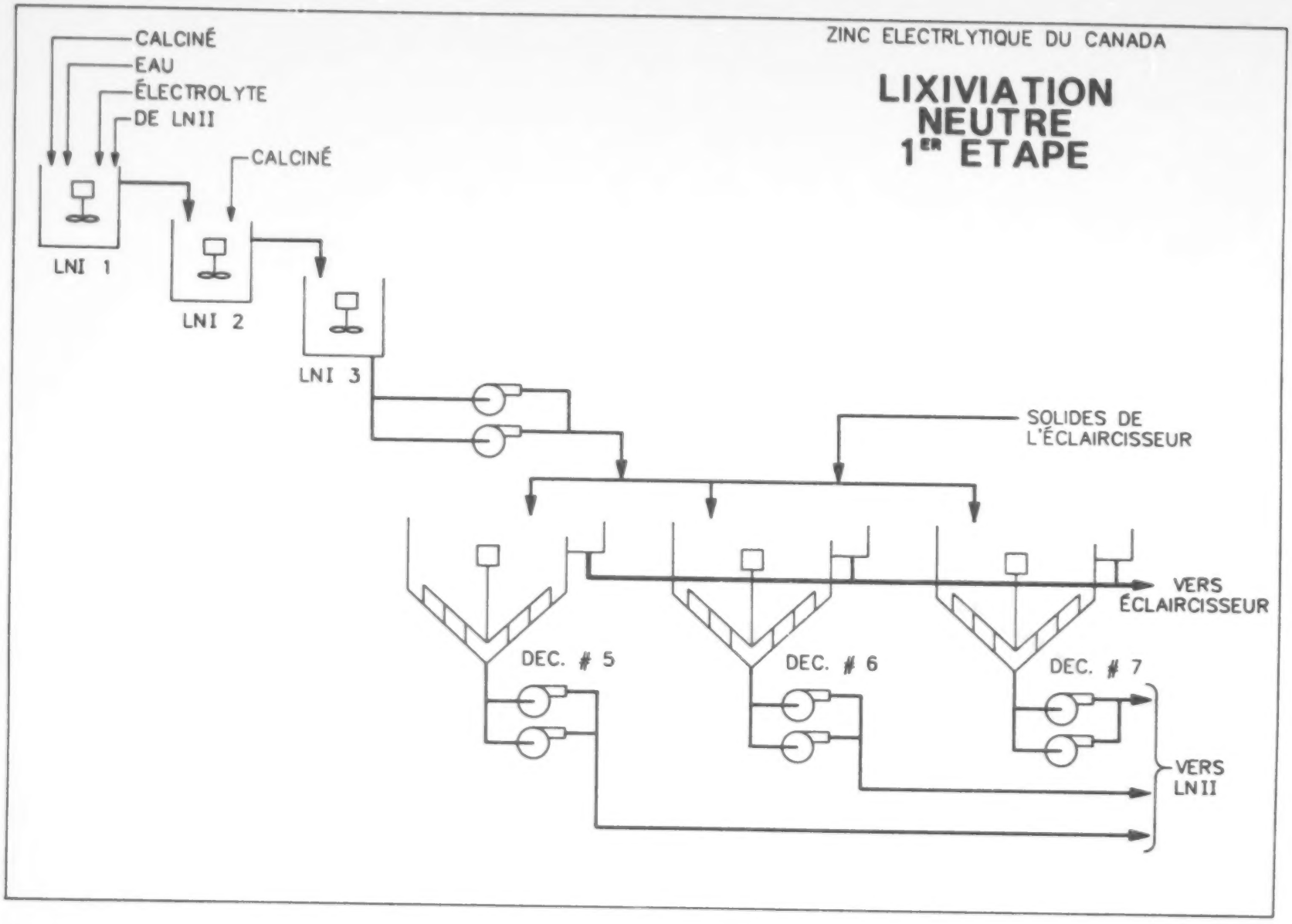
PROCESS

- The production phases
- Leach calcine feed
- Neutral leach stage 1

LES DIVERSES PHASES DE PRODUCTION




SILOS DE CALCINE
ZINC ELECTRLYTIQUE DU CANADA
LIXIVIATION ALIMENTATION EN CALCINE
SILO 1
SILO 2
SILO 3
SILO 4
SILO 5
SILO 6 1500 T
SILO
LNI 1
LNI 2
LNI 3
LIXIVIATION NEUTRE 1ère ETAPE


ZINC ELECTRLYTIQUE DU CANADA
LIXIVIATION
NEUTRE
1ER ETAPE
CALCINÉ
EAU
ÉLECTROLYTE
DE LNII
CALCINÉ
LNI 1
LNI 2
LNI 3
SOLIDES DE
L'ÉCLAIRCISSEUR
VERS
ÉCLAIRCISSEUR
DEC. # 5
DEC. # 6
DEC. # 7
VERS
LNII